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Spec Title: Capacitance Sensing - PC-Compatible USB CapSense Matrix Keyboard

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Capacitance Sensing - PC-Compatible USB CapSense Matrix Keyboard

AN2407

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Associated Part Family: CY8C21434-24LKXI
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Software Version: PSoC Designer™ 4.3 SP2
Associated Application Notes: AN2233a, AN2292, AN2318, AN2352, AN2355
PSoC Application Notes Index

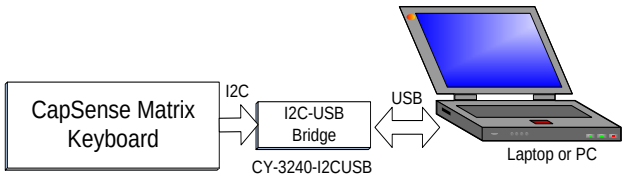
Application Note Abstract

This Application Note discusses construction, firmware communication, and considerations for a capacitive sensing matrixed keyboard using PSoC® CapSense.

Introduction

Capacitive sensor keyboards are widely used in modern compact devices. Keyboard sensors can be connected to the microcontroller pin individually. However, such a connection scheme limits the number of sensors to the number of available sensing pins. For applications with only a small number of sensors, this is not an issue. For keyboards with many sensors, a new connection scheme must be devised to maximize the number of sensors while maintaining a small pin count. Creating a matrix of sensors can drastically raise the number of sensors in an application without increasing the pin overhead needed to control them.

Figure 1. CapSense Matrix Keyboard Usage



This Application Note presents an example scheme for a matrixed capacitive sensing keyboard. A system block diagram is shown in Figure 1.

Technical specifications for the matrixed keyboard presented here are listed in Table 1.

Table 1. Matrix Keyboard Specification

Characteristic	Value
Total Keys Quantity	69 (64 matrix + 5 separated)
Matrix Structure	8x8
Sensor Dimension	11x11 mm
Communication Interface	I^2C™
Overlay Thickness	1-6 mm
PC Interface	USB, via I^2C-USB bridge
Power Supply Voltage	From USB 5 ± 0.25V
PC Implementation	Standard HID keyboard, no additional GUI required

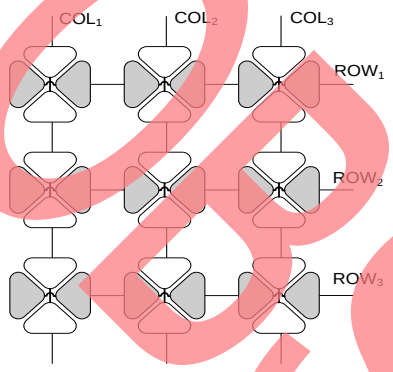
Keys Matrix Structure

Keyboard keys are organized into two groups. The first group is comprised of special function keys such as *Shift, Ctrl, Alt* keys. These keys are connected to PSoC pins individually and are scanned separately. The rest of the keys are organized in a rectangular 8-row, 8-column matrix. The 64 keys in this matrix represent alphanumeric keys as well as special keys such as WIN and EXC.

Shift, Ctrl, Alt and some other keys can be activated at the same time as other keys. Scanning these keys separately allows correct detection of simultaneous sensor activation of these and keys in the general matrix.

The sensor design implemented on the demonstration board increases the reliability of sensor activation detection. Each key consists of four segments. Segments opposite each other are connected to each other, creating two interwoven yet electrically distinct sensors for each key; there is a row sensor and column sensor for each key. Figure 2 illustrates the row (gray) and column (white) construction in two colors. This interwoven key structure means that a key represents activation on a row and a column at the same time.

Figure 2. Matrix Keys Structure

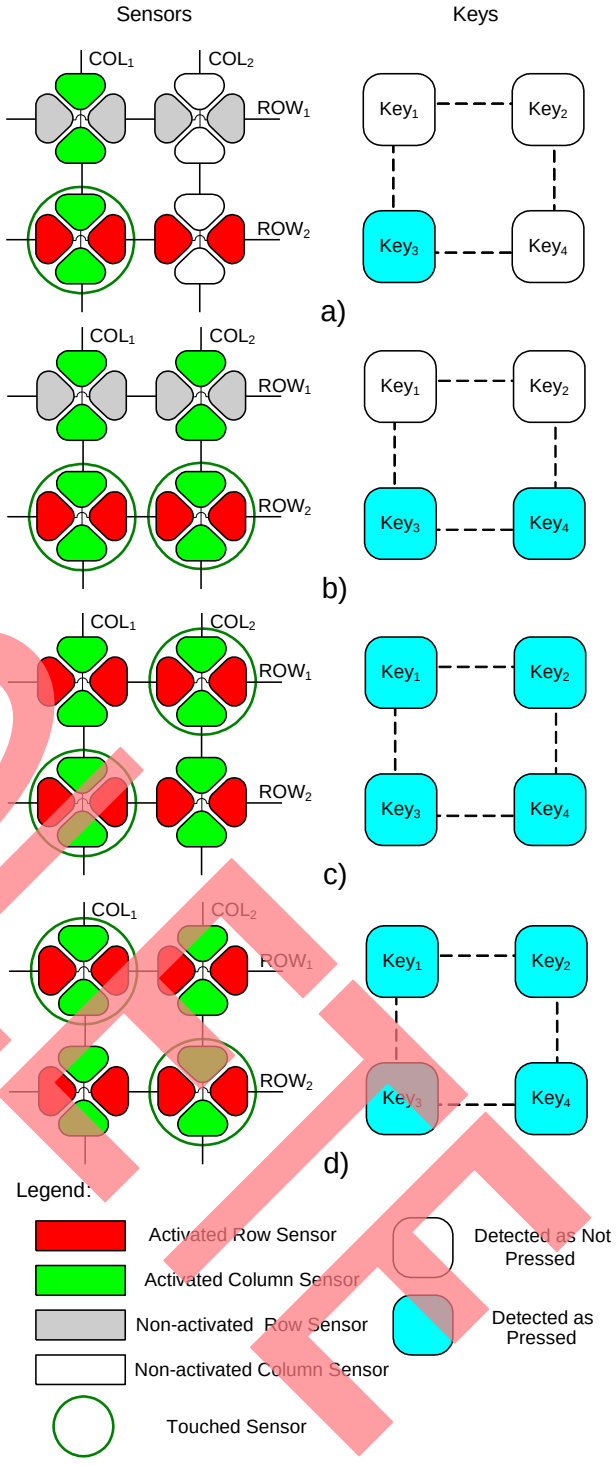


Firmware for activation detection completed an analysis of the row=column intersections. This method works well when only one key (one row and one column) is pressed at a time. If more than one key is pressed, false activations can occur due to multiple row-column activations.

Figures 3a shows the activation scheme for a single pressed key. Figure 3b shows the activation scheme for a simultaneous-key press that can be detected by the controller. Figures 3c and 3d show different simultaneous-key presses that exhibit the same activation state and cannot be distinguished. Two keys that do not show either a row or a column sensor, when pressed, are viewed as four active keys.

To avoid this phenomenon, keyboard design logic allows only one key to register as pressed by selecting only one row and column sensor at a time. The selected sensor is determined by using a sorting algorithm for signals.

Figure 3. Key Press/Sensor Activation Examples



Keyboard Schematic and PCB

The proposed keyboard uses minimal external components and no mechanical keys. All the keys are capacitive sensors implemented on the PCB as copper pads. The proposed keyboard consists of a PSoC and several resistors and capacitors. The keyboard schematic is shown in Appendix A. Series resistors are placed on each sensing trace and close to the PSoC. These resistors decrease the influence of the RF noise caused by cell phones, microwave ovens, etc. For more information on this, see AN2292, "Layout Guidelines for PSoC CapSense" and AN3218, "EMC Considerations for PSoC CapSense."

When multiple sensing elements are connected in parallel (sensors in rows and columns) the parasitic capacitance increases. A shield electrode is added behind the sensors to reduce this parasitic capacitance. The shield electrode is located on the bottom PCB layer.

Some sensors (*Space*, *Enter*) have much larger area than other sensors. This difference causes large sensor-to-sensor raw count variation, yielding different optimal modulator feedback resistor, R32 values. To balance raw counts for different sensors, resistor R27 is connected in parallel to the modulator capacitor when large area sensors are scanned. This connection is done in the firmware. For details on the modulator resistor and its impact on raw counts in CSD capacitive sensing, see AN2233a, "Capacitive Sensing Switch Scan/Theory and Operation." For information on how to determine the value of R32 for other applications, see AN2355, "Calibrating CapSense Applications."

Speaker LS1 is used to emulate the 'click' of a mechanical button. When key press is detected, PSoC generates a click signal on port P1[7] using a pulse width modulator (PWM). This signal is amplified through VT1 and played via speaker LS1.

Connector J3 is used for ISSP and for I2C data transfer.

The following requirements should be applied to board layout for optimal matrix keyboard performance.

- Reduce spacing between row and column sensors for each button (8-12 mill/0.2-0.3 mm).
- Keep the size and spacing of sensors consistent when possible.
- Use the physical key structure to determine the connection matrix structure for simplified layout.

The *Enter* and *Space* keys are not special function keys as are *Ctrl*, *Shift* and *Alt*. But they are very large by the mechanical design. Therefore, these keys have individual PSoC pins and are scanned with individual threshold parameters.

Keyboard Firmware

The PSoC Designer project for this Application Note uses the CapSense Sigma Delta (CSD) User Module (UM) for capacitive sensing and the EzI2C UM to transmit the results of the capacitive scans to the host though an I^2C interface. The firmware scans the individual and matrix sensors and sends the key codes to the I2C-USB bridge. Keys activation detection logic and sound generation is implemented in the firmware of the PSoC, not in the host or GUI. The CSD UM parameters are shown in Figure 4.

Figure 4. CSD UM Parameters

User Module Parameters	Value
FingerThreshold	150
NoiseThreshold	100
BaselineUpdateThreshold	200
Sensors Autoreset	Enabled
Hysteresis	40
Debounce	3
NegativeNoiseThreshold	20
LowBaselineReset	50
Scanning Speed	Normal
Resolution	10
Modulator Capacitor Pin	P0[1]
Feedback Resistor Pin	P1[5]
Reference	ASE11
Ref Value	0
ShieldElectrodeOut	Row_0_Output_1

A sorting algorithm is used to detect which buttons are really pressed when multiple keys are active. When a finger is near a key, non-zero signals exist on several neighboring key row and column elements at the same time. The activation may be on a particular key (row and column), but other rows and columns exhibit some signal as well. The most upper element is used to detect which element is really being pressed by the sensor when multiple sensors show possible activation.

After the active row and column are determined, the internal-use key code is derived using the following formula

```
KeyCode=(RowMaxSenNum<<3)+ColMaxSenNum[15]-8;
```

For *Shift*, *Ctrl*, *Alt*, *Space*, and *Return* key activation detection, CSD high-level APIs are used. After, the scanning key state is read from the CSD_baSnsOnMask[2] array.

When finger is between two keys, false activation is possible. To avoid this, an additional selection algorithm and hysteresis are used. A key pressed event is detected only when the signal from this key is two times or more greater than the signal from neighboring keys. If it is not, the key activation state is not changed.

USB HID Device

To test and demonstrate the matrix keyboard unit, we use special firmware that was developed for Cypress, I2C to USB Bridge Kit CY3240-I2USB. The PC operating system detects the I2C-USB bridge as an HID keyboard. The bridge firmware converts internal key code to HID key codes. We used two different PSoC devices for sensor scanning (CY8C21434-24LKXI) and USB communication (CY8C24894-24LFXI). It is possible to implement this design using a single CY8C24794-24LKXI, which supports both CSD capacitive sensing and USB communication.

When a user holds a finger on the button for a long time, the PC operating system automatically runs character auto-repeat. This is implemented by the operating system, not the I2C-USB bridge.

The USB HID keyboard endpoint descriptors and HID report description are shown in Figure 5 and Figure 7. The Windows device manager screen is shown in Figure 6.

Figure 5. USB HID Keyboard Endpoint Descriptors

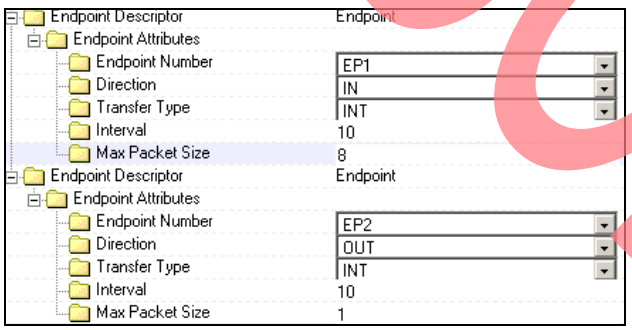


Figure 6. Windows Device Manager

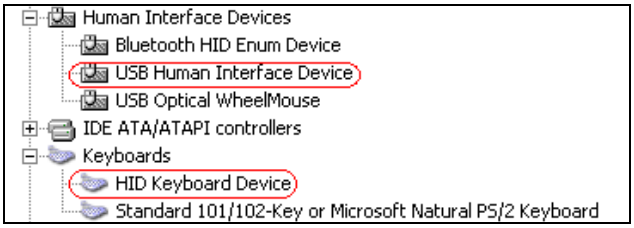
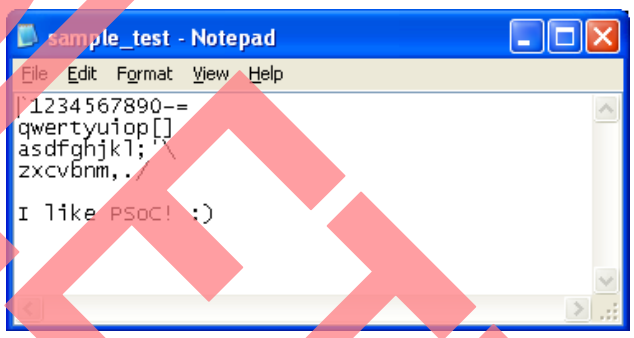


Figure 7. HID Report Description

The sample text in Figure 8 was typed using the USB CapSense Matrix Keyboard.

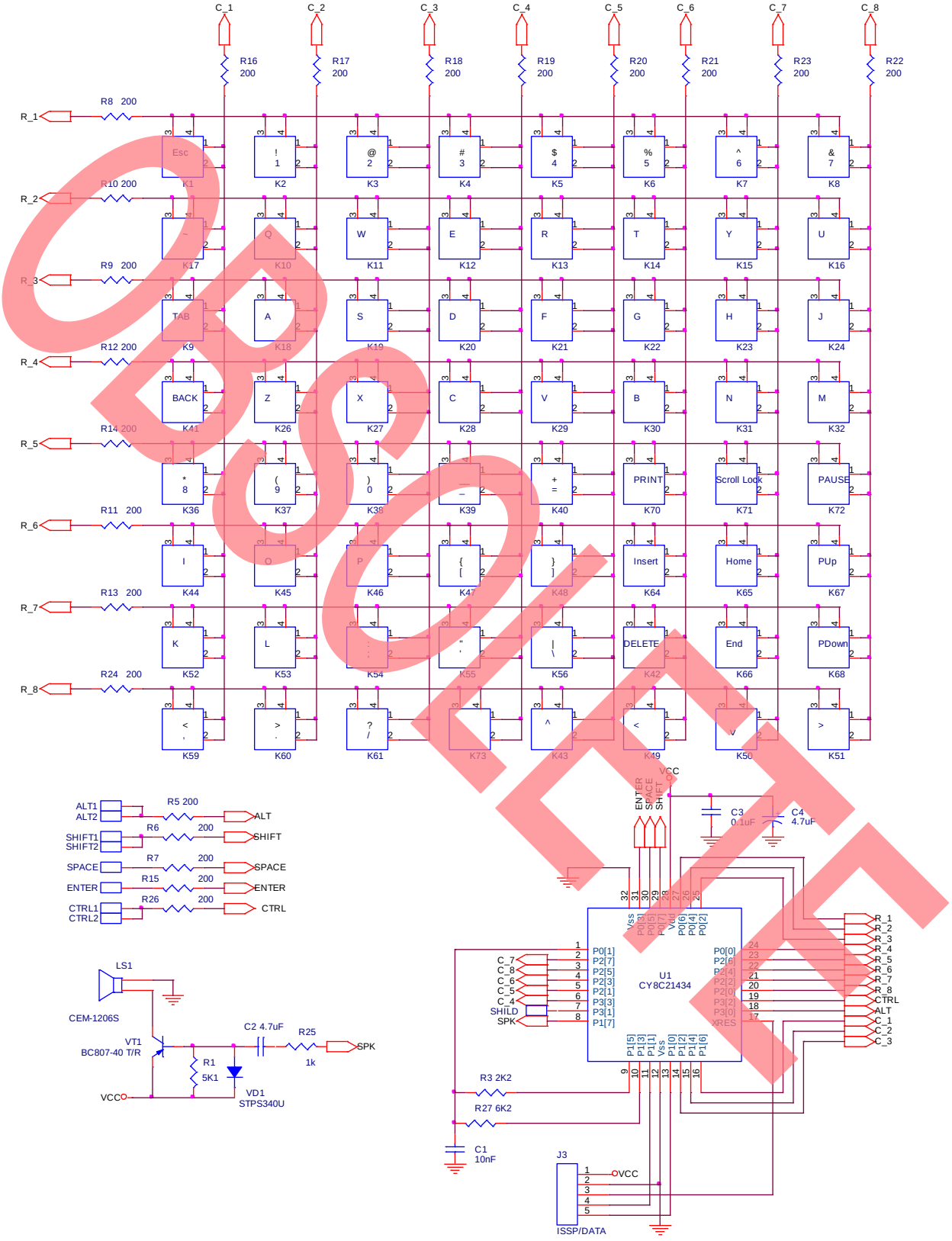
Figure 8. Sample Text



The matrix keyboard PCB pictures are shown in Appendix B. Gerber files are included in the project archive for reference.

The CapSense matrix keyboard with I2C-USB bridge photo is shown in Appendix C.

Appendix A. Keyboard Schematic



Appendix B. Keyboard Layout

Figure 9. PCB Top. Scale 50%

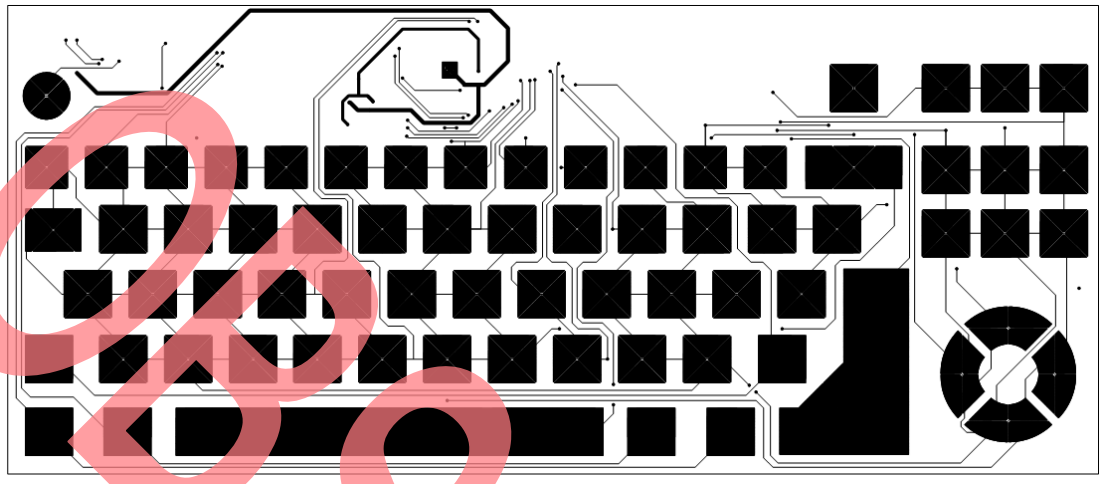


Figure 10. PCB Bottom. Scale 50%

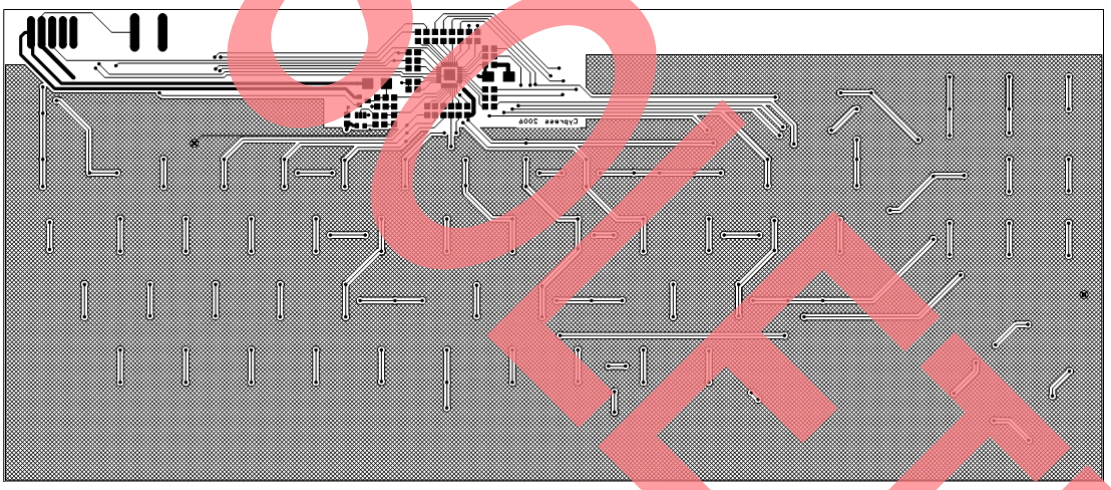
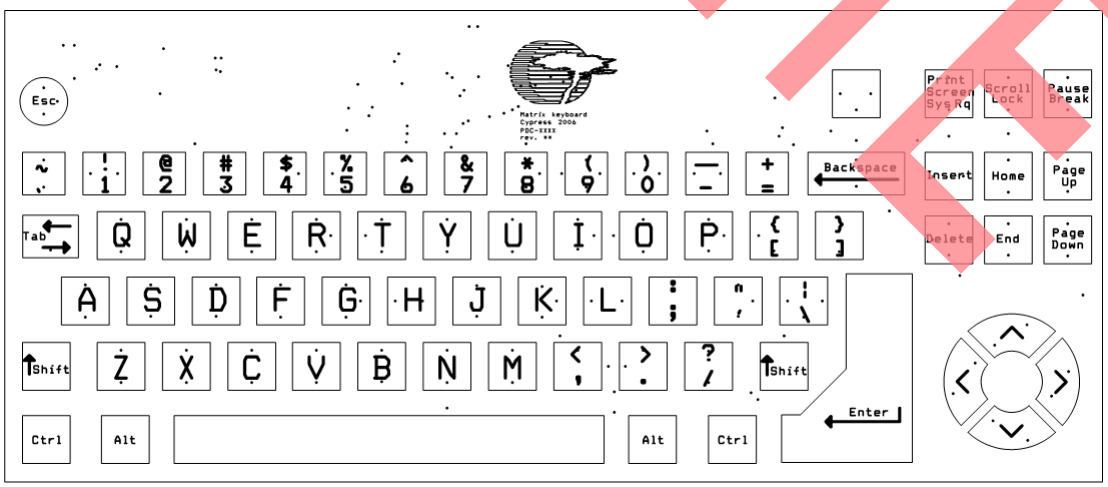


Figure 10. PCB Silk Screen Top. Scale 50%



Appendix C. Device Photo

Figure 12. CapSense Matrix Keyboard with I2C-USB Bridge Photo

Document History

Document Title: Capacitance Sensing - PC-Compatible USB CapSense Matrix Keyboard – AN2407

Document Number: 001-41442

Revision	ECN	Orig. of Change	Submission Date	Description of Change
**	1541809	ANBA	10/04/2007	New spec.
*A	3407058	ZINE	10/14/2011	Obsolete spec.

In March of 2007, Cypress recataloged all of its Application Notes using a new documentation number and revision code. This new documentation number and revision code (001-xxxxx, beginning with rev. **), located in the footer of the document, will be used in all subsequent revisions.

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